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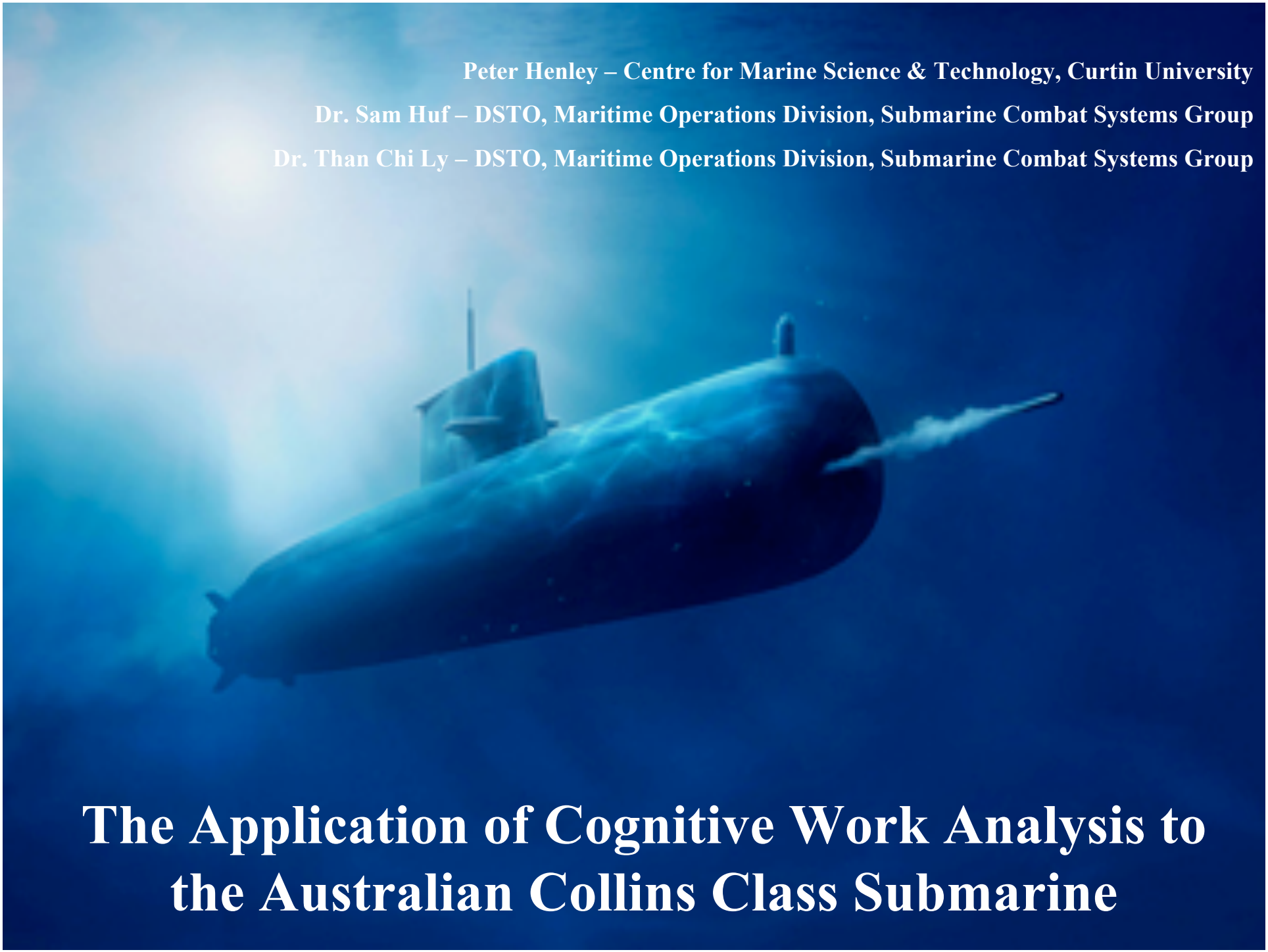


The Application of Cognitive Work Analysis to the Australian Collins Class Submarine

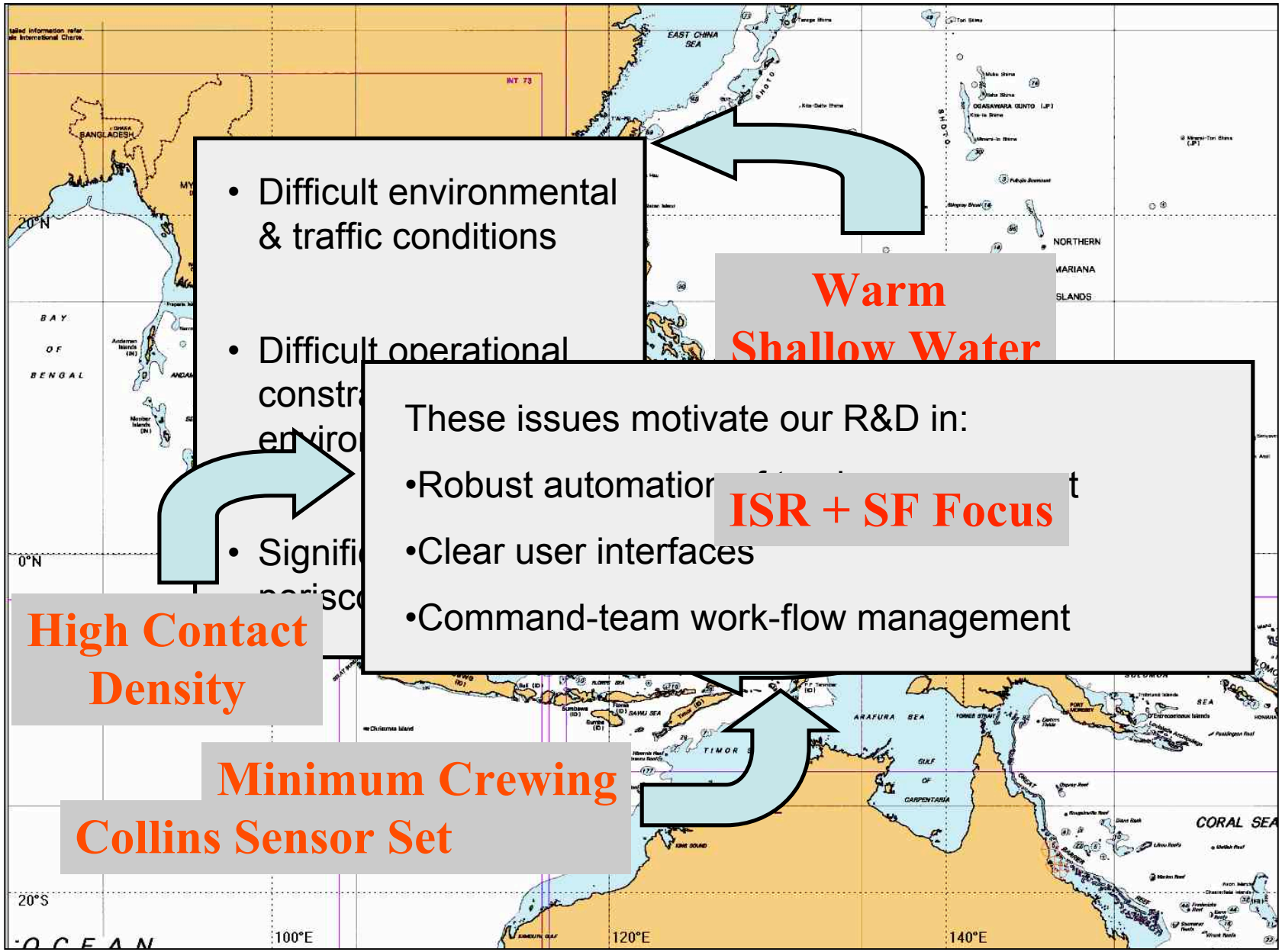
Presentation Outline

- Why Analyse?
- Why Cognitive Work Analysis?
- Overview of the Cognitive Work Analysis Methodology
- Work Domain Analysis
- Control Task Analysis
- Future Directions.

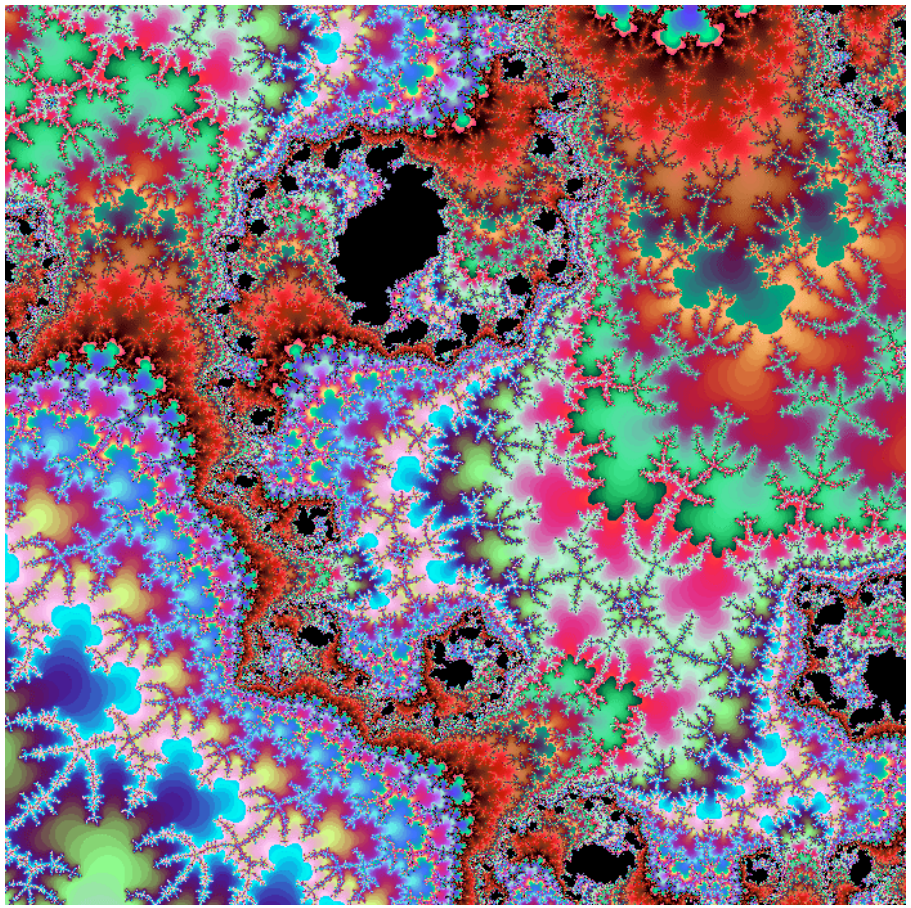
WHY ANALYSE?

- To improve the quality of information support available to RAN submarine command teams
- Poor performance of previous Collins class combat systems
- Ensure that RAN requirements from the evolutionary acquisition of the AN/BYG-1 combat system are met – think ahead of the development cycle
- Input into next generation submarine design
- Achieving more with fewer people
  - Operations in the littoral
  - Network centric warfare
  - Changing public perceptions of safety and acceptable risk
  - Demographic changes and increased competition for personnel
- Looking beyond current process and command team structure.

COLLINS CLASS OPERATIONAL CONTEXT



WHY COGNITIVE WORK ANALYSIS?



- A submarine in its working environment is a good example of a complex socio-technical system
- The command team of a submarine is faced with a very large problem space where no two operational situations will ever be exactly identical, and which may not be predictable
- A submarine is not a closed system – it is affected by external environmental and tactical disturbances which cannot be predicted with any certainty
- How do you design information support for situations that may not have been predicted during design?

COMPLEXITY IN SUBMARINE OPERATIONS

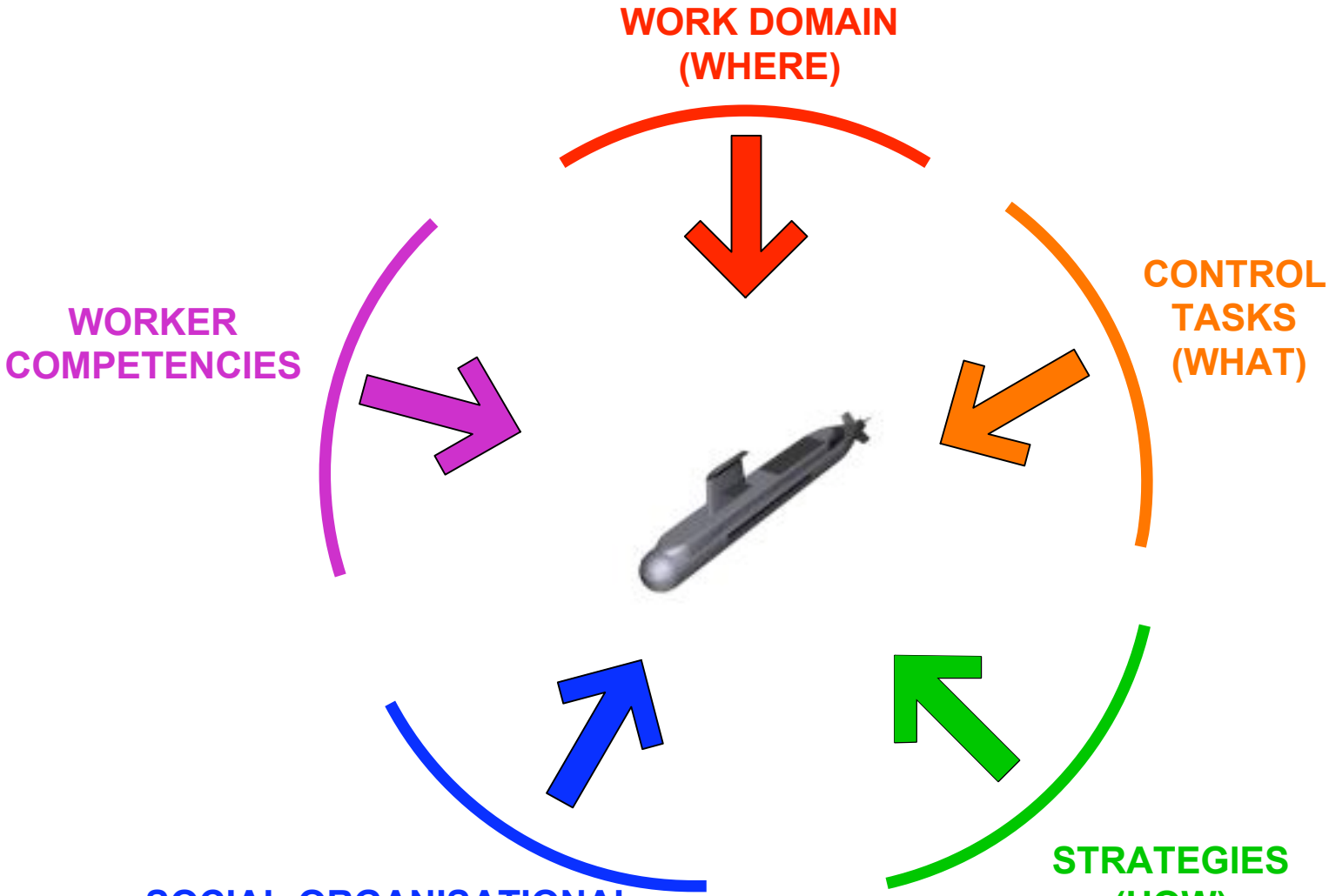
(After Vicente, 1999)

- Large problem spaces
- External disturbances
- High levels of uncertainty
- High hazard levels
- Coupled systems
- Automation
- Mediated interaction
- Distributed control and coordination
- Social coordination and communication
- Heterogeneous perspectives.

WHAT IS COGNITIVE WORK ANALYSIS?

- **Based on the concept of behaviour-shaping constraints – that act to limit, but do not usually uniquely specify, the action-choices of workers or automation**
- **Integrated multi faceted framework for the work analysis of complex systems**
- **Ecological perspective – analysis starts with the physical work domain and moves progressively inwards to the operator's cognitive processes**
- **Maximisation of context-conditioned variability of response of the operators - "The worker finishes the design".** (Rasmussen)

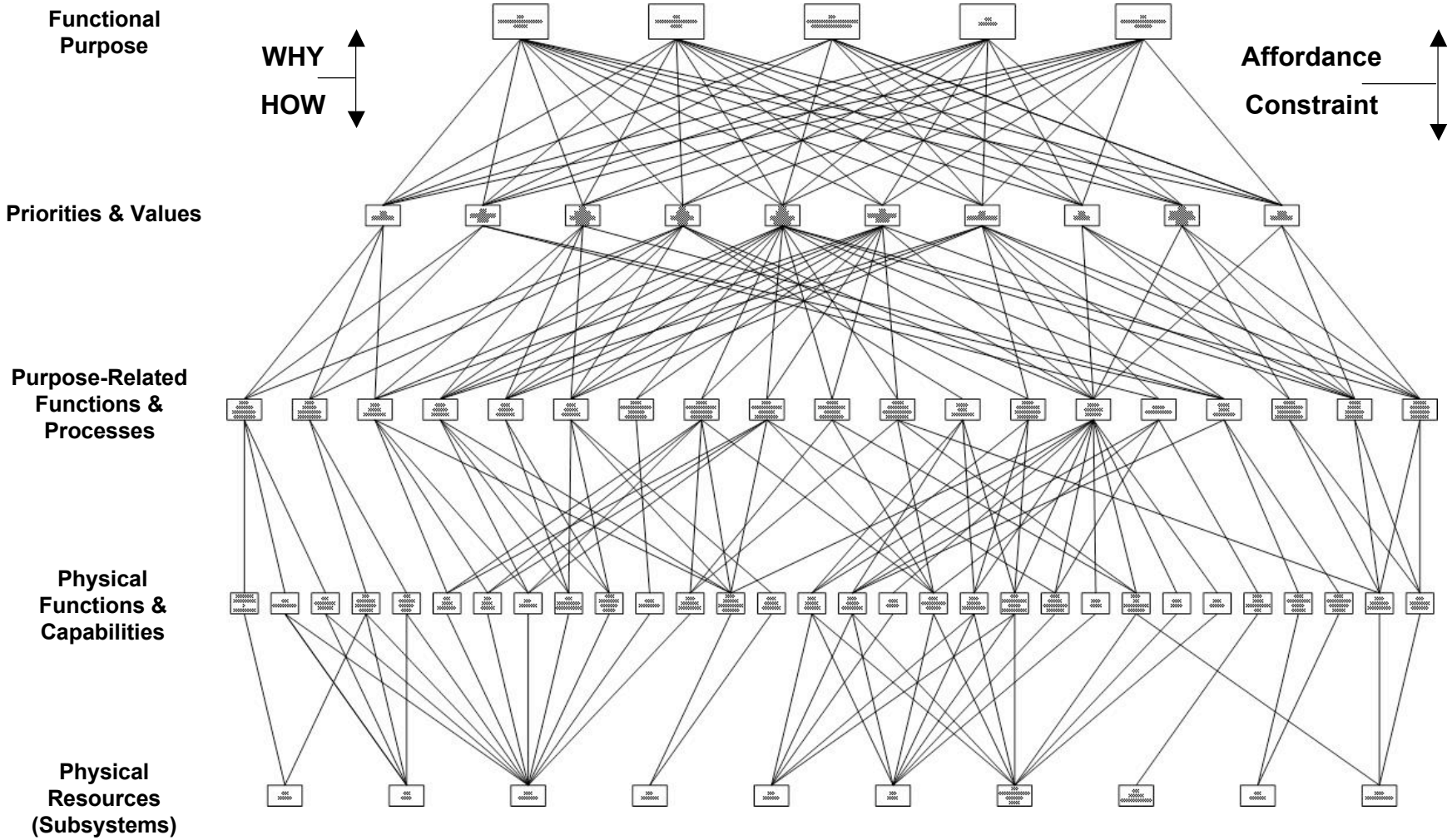
SOURCES OF CONSTRAINT



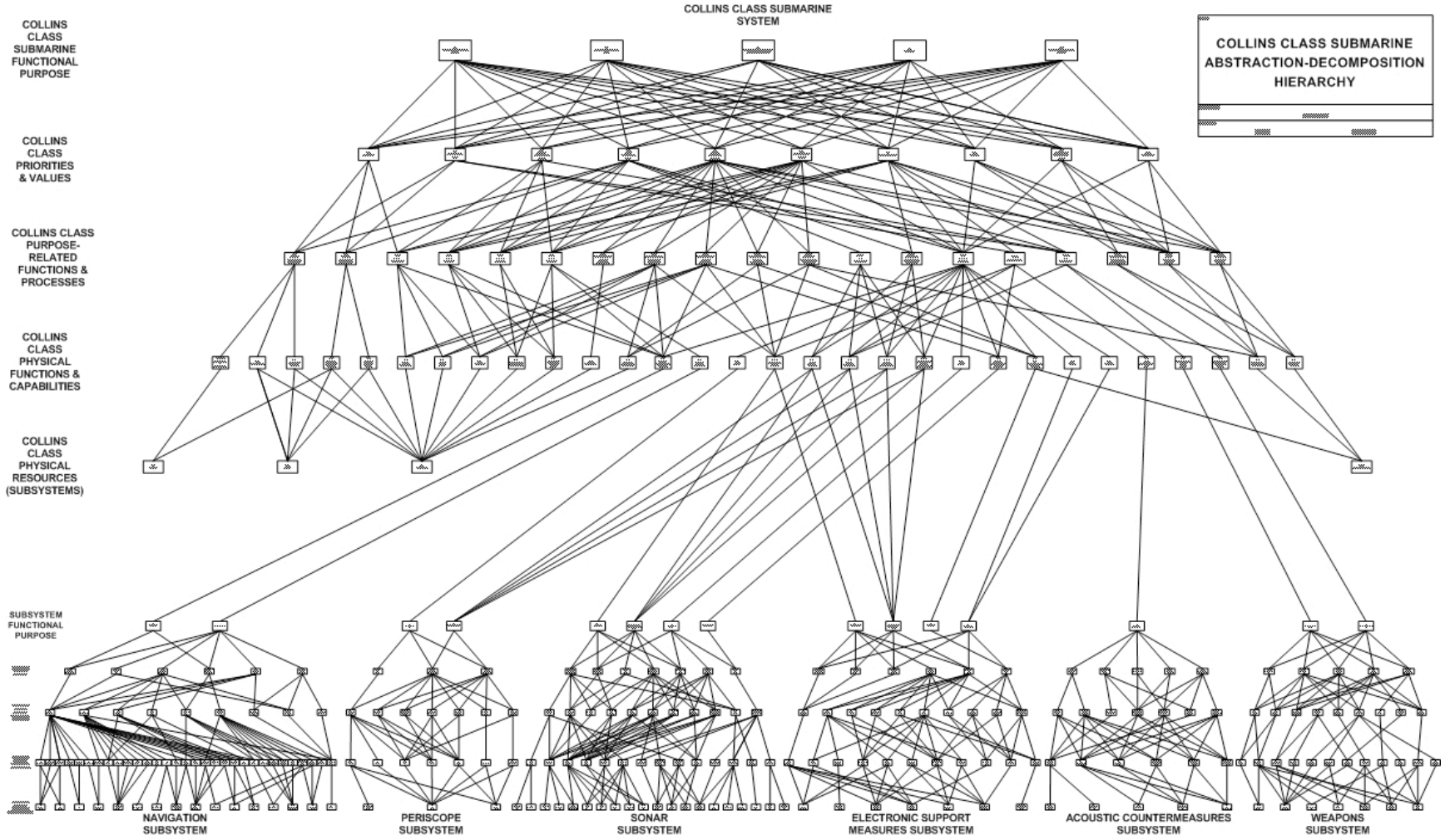
WORK DOMAIN ANALYSIS

- Purpose orientated, functional mapping of the entire work domain – examines WHERE work is carried out
- Device independent – no reliance on existing computer-based interface or automation
- Task independent – identifies knowledge of domain-based constraints and affordances that are available across all possible tasks and situations
- Examines the work domain at different levels of functional abstraction and physical deconstruction
- Examines the work domain as a system of systems

WDA ABSTRACTION HIERARCHY



WORK DOMAIN ANALYSIS – "WHERE"



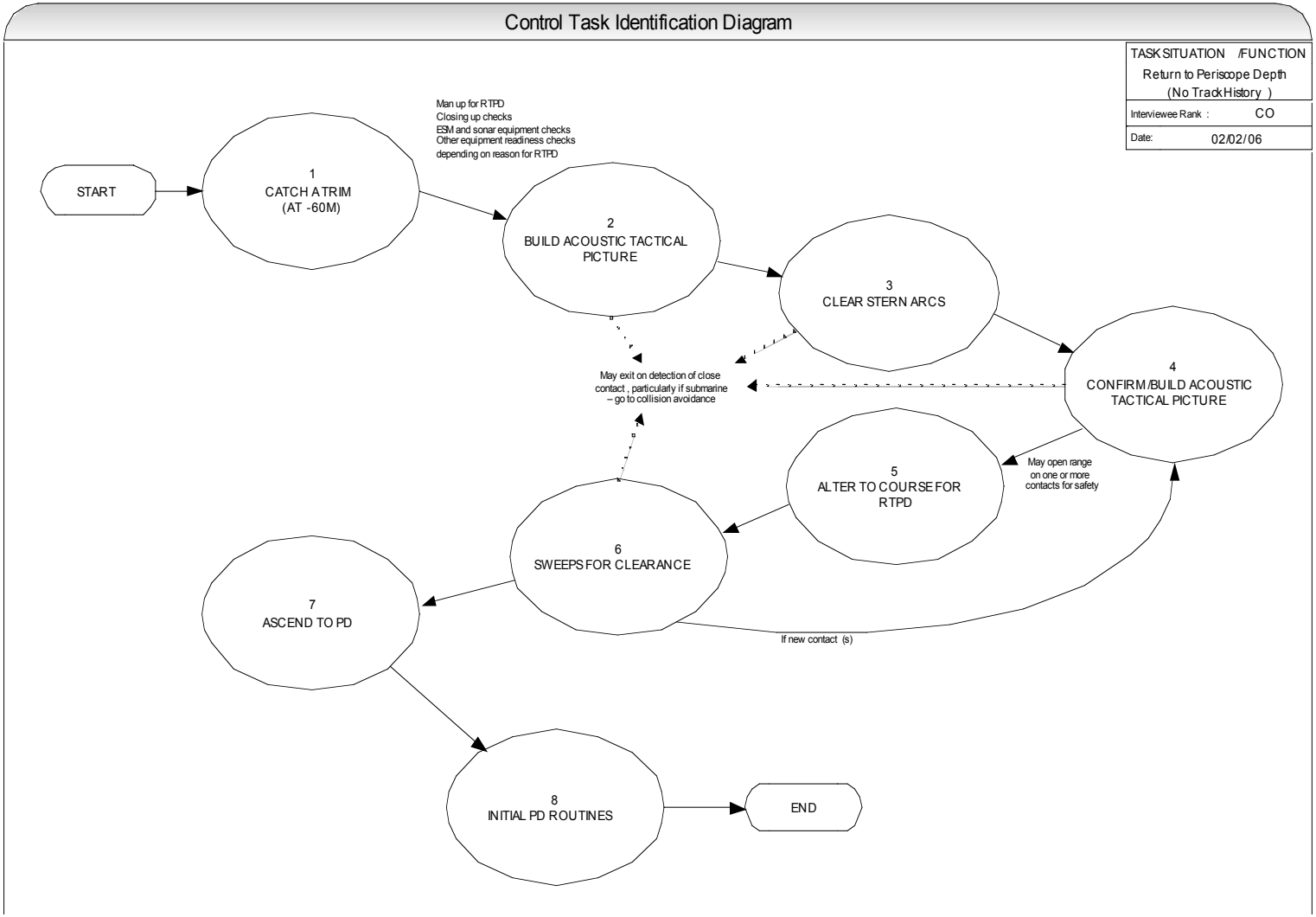
WDA OUTPUTS

- **WDA provides different viewpoints of the same work domain**
  - **Defines the information requirements of operators as they focus on different levels of abstraction and decomposition during problem solving**
  - **Provides an explicitly goal-orientated knowledge structure for problem solving**
  - **Less detailed information at higher levels of abstraction – allows resource-limited operators to filter what would otherwise be an overwhelming data load**
  - **Allows operators to rapidly constrain the problem space by starting at a high level of abstraction, then drilling down to specific areas of interest – typical of expert behaviour**
  - **Definition of sensor and modeling requirements.**

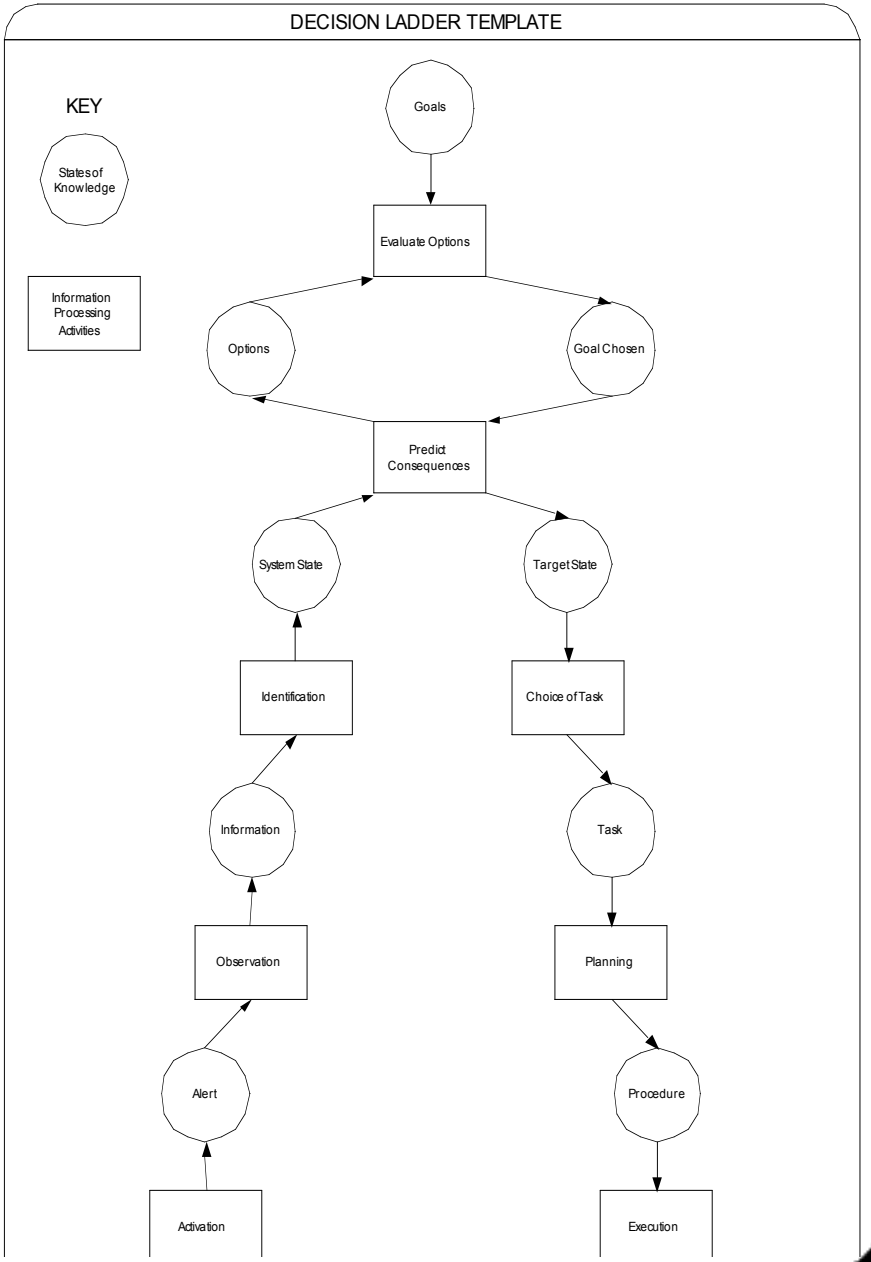
CONTROL TASK ANALYSIS

- Examines WHAT is done within the work domain by means of detailed expert interviews
- Provides a formative task analysis methodology to ensure support for unforeseen circumstances
- Maps the cognitive trajectories of operators onto a standard template – especially shortcuts
- Identifies a toolbox of prototypical control and information-processing tasks
- Uses input-output analysis to identify knowledge inputs and outputs, and the constraints that govern information-processing.

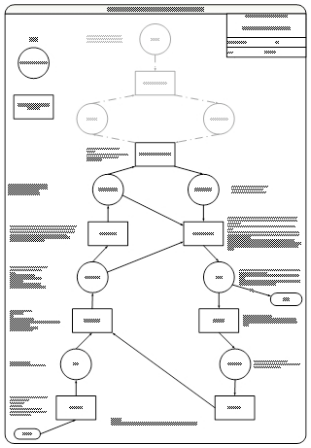
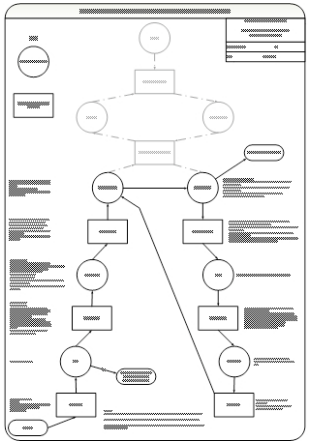
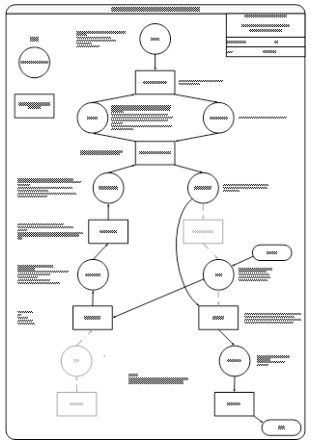
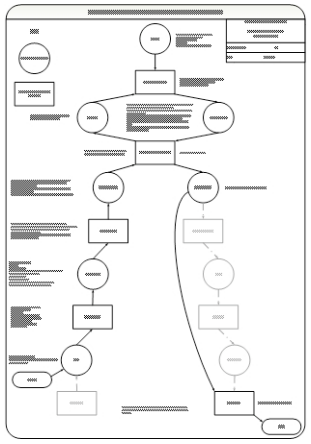
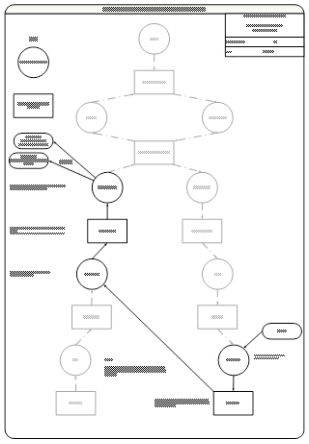
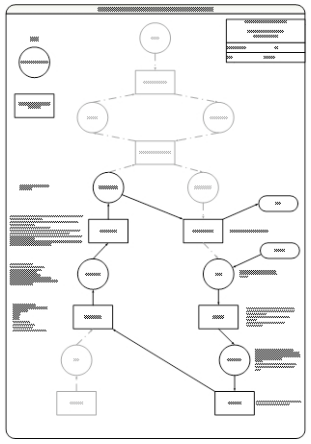
CONTROL TASK ANALYSIS – "WHAT"



THE DECISION LADDER TEMPLATE



DECISION LADDER SEQUENCE

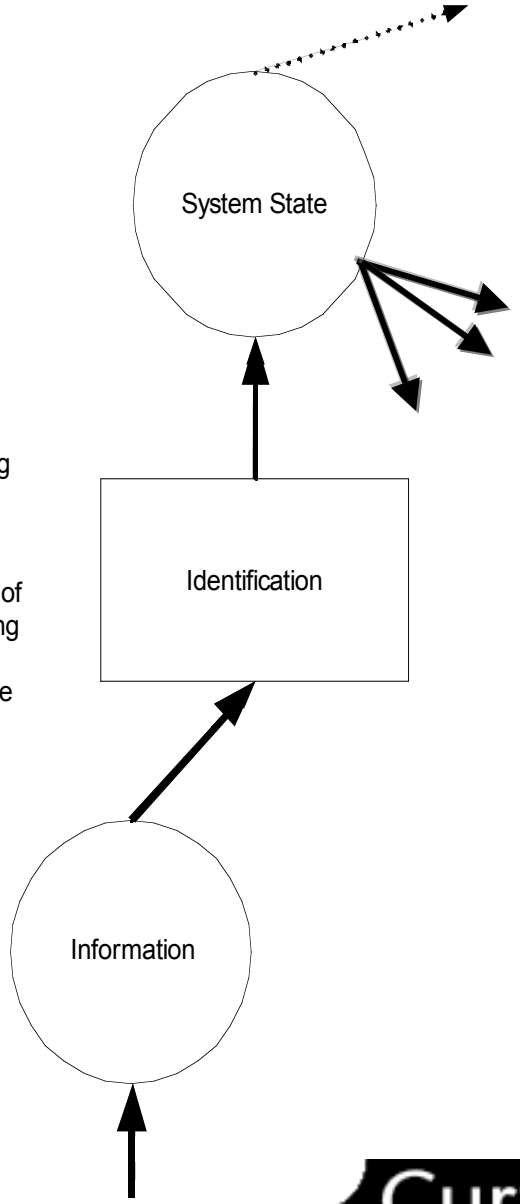







INPUT/OUTPUT/ CONSTRAINT ANALYSIS

- Identify priority/high risk contacts (close or converging)
- Contact relative bearings
- Contact range, course & speed
- Recognise ambiguous or low confidence data

- High bearing rate implies close contact
- Low bearing rate plus high or increasing intensity implies closing contact
- 'Wide' contacts on A-scan tend to be closer
- For each contact examine combination of width, intensity, intensity variation, bearing and bearing rate
- ROD accuracy will flow through to range estimates

- Contact bearing
- Contact bearing rate
- Contact range
- Contact intensity
- Contact intensity variation
- Pre/Post CPA
- Contact speed
- Contact 'width' on A-scan display
- Range of the day



CONTROL TASK ANALYSIS OUTPUTS

- Identification of the requirements for proficient control
- Identification of cognitive shortcuts, and the circumstances that trigger their use
- Definition of a minimally sufficient information set for prototypical control tasks and information processing steps that can be assembled "on the fly" by operators into efficient and flexible responses to problems within the work domain
- Context-sensitive interface design
- Automation design
- Procedural information in terms of sequence constraints.

CURRENT STATUS OF COLLINS CLASS COGNITIVE WORK ANALYSIS

- **Concentrating on tactical and operational vessel control at the Watchleader/OOW level – effective overall control**
  - **Work domain analysis approximately 80% complete**
  - **Validated by means of subject matter expert interviews**
  - **Very stable, although we expect incremental change as we progress through the CWA methodology**
  - **Major subsystems remain unexamined – Engineering being the largest**
  - **Control task analysis carried out on a single prototypical work situation leading to a preliminary knowledge and information processing listing.**

FUTURE DIRECTIONS - INTERFACE DESIGN

- **Work Domain Analysis**
  - **Communications subsystem has been analysed**
  - **Engineering subsystem to be analysed in the near future**

- **Control Task Analysis**
  - **2-3 additional prototypical work situations to be analysed**
  - **Greater emphasis on situations outside normal SOPs**

- **Strategies Analysis**
  - **All control task information processing triplets to be analysed for strategy content and the triggers that govern strategy selection**

- **Link to existing Command Tactical Picture development project**
  - **General and context-sensitive content**
  - **Scenario-based simulation testing.**

FUTURE DIRECTIONS – SOCIO-ORGANISATIONAL AND SKILLS ANALYSES

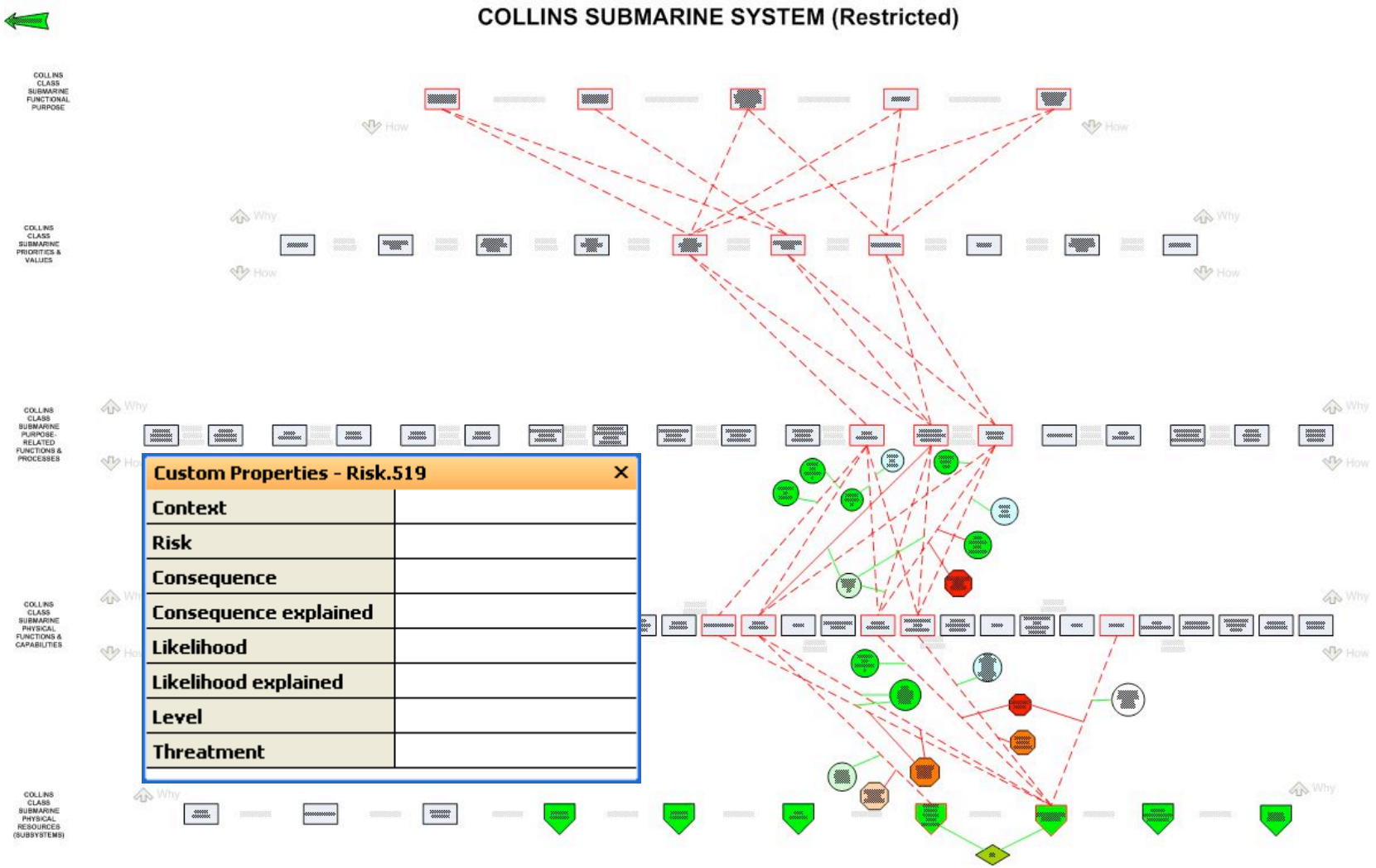
- Existing project to map the knowledge, skills and competencies held by every position in the Collins crew organisation – immediate linkage with our own competencies analysis phase
- Particular interest in discovering how and where these skills are actually used during the various phases of a submarine deployment
- We intend to map this information onto the WDA abstraction-decomposition hierarchy and the analysed control tasks
  - Functionality-based mapping of effort and cooperation – does it match the command team structure?
  - Insight into current organisation and how it might be changed to improve performance
  - Position and task-based interface requirements
  - Insight into individual crew positions and how these might be changed to improve performance, satisfaction and retention.

FUTURE DIRECTIONS – AN/BYG-1 EVOLUTIONARY ACQUISITION

- Regular cycle of software and hardware upgrades
- Need to get ahead of the delivery cycle
- Need to be able to make informed judgments as to the suitability of proposed changes to the particular needs of the Collins class command teams
- Potential new uses for the WDA abstraction-decomposition hierarchy:
  - SSN/Collins functional comparison for capability assessment
  - New technology impact assessment
  - Allocation of measures of performance for quantitative assessment of change.

FUTURE DIRECTIONS – AN/BYG-1 DEVELOPMENT

AS/NZS 4360:2004



SUMMARY

- A pilot study into the application of cognitive work analysis to the tactical control of a conventional submarine has been successfully completed
- The results obtained justify further work, and the eventual employment of the full range of the component analyses of the methodology
- The intention is to design interface/display components that can be tested in scenario-based, human in the loop simulation studies to provide quantitative data on performance improvement
- At the same time, efforts are being made to use the different descriptions obtained of the work domain, and the tasks undertaken within it, to help manage the technological development of the future Collins class combat systems
- The results of the cognitive work analysis process are also being used to aid modeling in areas of human resource management.